Lawrence Livermore National Laboratory

Laser Science & Technology

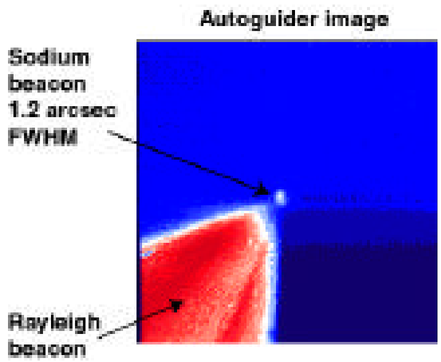
Dr. Howard T. Powell, Program Leader

UCRL-TB-136126-00-07

Laser Guide Star (LGS) Systems at Lick and Keck Observatories

Adaptive optics have revolutionized optical astronomy over the last few years. These systems perform real time compensation of image distortions caused by atmospheric turbulence by sensing the distortions and correcting them. Typically, bright natural stars serve as reference beacons for the adaptive optics to sense the distortions, but, unfortunately, less than 1% of the sky has natural stars bright enough to use for correction. Under the support of LDRD and UC Relations Program, we are working with the Information Science and Technology Program to develop a fieldable sodium-layer LGS system for use on large astronomical telescopes in the Keck Observatory. Using an LGS at 589 nm, artificial stars can be created in the direction of observation by laser-induced flourescence in the mesospheric sodium layer, 90 km above the earth's surface. Using LGS beacons enables the collection of diffraction limited images over 60% of the sky.

In 1992,an LGS feasibility demonstration was performed at LLNL, propagating 1100 watts from the AVLIS laser chain into the sky to form a sodium guide star visible from the ground with the naked eye. In 1996, workers from AVLIS program (Herbert Friedman, et. al) installed a 20 W version of this laser, equipped with 127 elements adaptive optics, at the Lick Observatory on Mt. Hamilton, California and achieved significant image improvement on the 3-m Shane telescope. This system, using four pulsed, frequency-doubled Nd:YAG lasers to pump a dye master amplifier, preamplifier, and amplifier, produces up to 20 W at 11 kHz. The Lick AO/ LGS system is now performing near theoretical limits, achieving a Strehl ratio as high as 0.4. A recent image of the sodium beacon on the sky, along with the Rayleigh scattered light from aerosol scattering in the lower atmosphere, is shown in the following photo. Recent improvements to the LGS system have dramatically improved the beam quality and system performance. The focus of the Lick LGS project is support of science observations and improving the LG S system for routine use.



A similar AVLIS laser system was delivered to the Keck Observatory in Hawaii for use on one of the twin 10-m telescopes. This was installed at Keck headquarters in Waimea, Hawaii in 1998, prior to full completion of the laser system. Numerous modifications and upgrades to the earlier LGS design have now been made to meet the evolving requirements for a reliable, robust, and remotely operable system, allowing safe operation at 14,000 ft. Among the changes made were the installation of safety interlocks and diagnostics to prevent optical damage to the system. We redesigned the relay optics to reduce hard edge diffraction in the dye laser, while optimizing power and beam quality. Motorized waveplates with polarizers in the YAGs allow remote power balancing between amplifier pump beams. This significantly reduces the jitter of beam pointing. To extend the lifetime of frequency doubling of the YAG lasers, we replaced KTP with LBO crystals. Automated startup and shutdown sequencing has also significantly reduced the rate of damage in the system.

Several 8-hr/day laser runs have been performed at Keck (see photo) and have demonstrated excellent stability and beam quality. A run in June demonstrated an average power of 14.8 W with 1.5% energy stability and a Strehl ratio of 0.647. In addition, a 5 day, 8 hr. per day operations test was just completed, demonstrating the improved reliability of the system. The Keck LGS modifications should be complete later this year. Planning for the move to the summit of Mauna Kea will begin in August with system deployment on the Keck II telescope expected by early 2001. The Keck LGS uses frequency-doubled Nd:Yag laser as it's pump source. The dye oscillator and pump lasers will be installed on the floor of the telescope dome and will be fiber-optically coupled to the dye amplifiers mounted on the elevation ring of the telescope.

A recent Decadal Review by the National Academy of Sciences identified the construction of a large-aperture telescope as the highest priority for ground-based astronomy in the next decade. The California Extremely Large Telescope (CELT) is a 30-m telescope proposed for construction by 2010, as a collaboration between U. C. and Caltech. The capability to use multiple laser guide stars routinely was identified as the primary key enabling technology for these next generation telescopes. Multiple lasers guide stars will be required to compensate for turbulence across the increased telescope aperture. As a result, it is clear that development of a compact, robust, reliable solid-state guide star laser technology is required. This year we received funding to identify the most promising laser technology for further development. The design we selected is based on sum-frequency mixing of two fiber lasers in a periodically poled crystal to produce a 10 W, CW beam at 589 nm. Technology demonstrations will begin in FY01.

(Dee Pennington)

For comments about content of the *LS&T Program Update*, contact Dr. Hao-Lin Chen (925) 422-6198.
To get on the mailing list of the *LS&T Program Update*, send a request to Kim Baynes, baynes1@llnl.gov.
This work was performed under the auspices of the U.S. Department of Energy by
University of California Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.